APPENDIX K
AIRBORNE PATHWAY MODELING

K.1 Generic Sites

Two generic sites were selected to represent locations where various uranium mines are present. The characteristics of these sites, as shown in Table K.1, were used in the AIRDOS-EPA code (Mo79).

Table K.1 Characteristics of the generic sites

	New Mexico (Ambrosia Lake)	Wyoming (Gas Hills)
Meteorological data:	Grants/Gnt-Milan (WBAN=93057)	Casper (WBAN-24089)
Stability Categories	A-F	A-G
Period of Record:	54/01-54/12	67/01-71/12
Annual Rainfall:	20 cm	29 cm
Average Mixing Height:	800 m	500 m
Mean Ambient Temperature:	13.8°C	7.4°C
Atmospheric dispersion factors (Chi/Q) for maximum individual:		
gases	5.5 E-6 sec/m^3	2.5 E-6 sec/m^3
particulates	1.4 E-6 sec/m^3	1.0 E-6 sec/m^3
Population: (0-80 km):	3.60E+4 persons	1.43E+4 persons
Dairy Cattle (0-80 km):	2.30E+3 head	1.17E+3 head
Meat Animals (0-80 km):	8.31E+4 head	1.03E+5 head
Vegetable Crop Area: (0-80 km)	2.78E+3 ha	3.20E+3 ha

The model active and inactive underground mines were assumed to be situated at the New Mexico site (see Section 2). The Wyoming site was used for both the model active and inactive surface mines and the model in situ leach mine (see Section 2).

K.2 Meteorological Data

Joint frequency distributions by stability category were obtained from the National Climatic Center (NOAA-Asheville, NC). These distributions are identified in Table K.1 by location, stability category range, and period of record.

The average mixing height (Table K.1) is the distance between the ground surface and a stable layer of air where no further mixing occurs. This average was computed by determining the harmonic mean of the annual morning mixing height and the annual afternoon mixing height for the location (Ho72). The rainfall rate determines the value used for the scavenging coefficient. No attempt was made to be any more accurate than one significant figure for both average mixing height and scavenging coefficient. Both sites are relatively dry locations, as reflected by a scavenging coefficient of 2.0×10^{-6} sec^{-1}. A dry deposition velocity of 1 cm/s was assigned to particulates, while radon was assumed to be non-depositing.

K.3 Population

The population data for both generic sites were generated by a computer program (At74) that uses an edited and compressed version of the 1970 United States Census Bureau's "Master Enumeration District List with Coordinates" containing housing and population counts for each census enumeration district (CED) and the geographic coordinates of the population centroid for the district. In the Standard Metropolitan Statistical Areas, the CED is usually a "block group" that consists of a physical city block. In other areas, the district used is called an "enumeration district", and it may cover several square miles in a rural area.

There are approximately 250,000 CED's in the United States and the average population is about 800. The position of the population centroid for each CED was marked on the district maps by the individual census official responsible for each district and is based only on his judgment from inspection of the population distribution on the map. The CED entries are sorted in ascending order by longitude on the final data tape.

K.4 Dairy and Meat Animals

Dairy cattle and meat animal distributions are part of the AIRDOS-EPA

input. A constant animal density is assumed. The animal densities are provided by state in Table K.2. These densities were derived from information developed by NRC (NRC75). Milk production density in units of liter/day-square mile was converted to number of dairy cattle/square kilometer by assuming a milk production rate of 11.0 liters/day per dairy cow. Meat production density in units of kilograms/day-square mile was changed to an equivalent number of meat animals/square kilometer by assuming a slaughter rate of 0.00381 day^{-1} and 200 kilograms of meat/animal slaughtered.

Table K.2 Animal and vegetable crop distributions for use with AIRDOS-EPA

State	Dairy Cattle Density ($No./km^2$)	Meat Animal Density ($No./km^2$)	Vegetable Crop Fraction (Km^2/km^2)
New Mexico	1.14E-1	4.13	1.38E-3
Wyoming	5.79E-2	5.12	1.59E-3

K.5 Vegetable Crop Area

A certain fraction of the land within 80 km of the source is used for vegetable crop production, which is assumed to be uniformly distributed throughout the entire assessment area. Information on the vegetable production density in terms of kilograms(fresh weight)/day-square mile was obtained from NRC data (NRC75). The vegetable crop fractions (Table K.2) by state were computed from the production densities by assuming a production rate of 2 kilograms (fresh weight)/year-square meter (NRC77).

K.6 Food Intake

Table K.3 summarizes the ingestion values used for both generic sites for the maximum individual. These values are based on a USDA report (USDA72) for a rural farm situation. F1 and F2 are the percentages produced at the

individual's home and within the 80 km assessment area, respectively. The balance of the diet, F3, is considered to be imported from outside the assessment area with negligible radionuclide concentrations due to the assessed source. The F1 values are obtained by dividing the home-produced quantity by the quantity from all sources. The meat values include a combination of beef and pork. The vegetable values only include fresh vegetables.

Table K.3 Sources of food for the maximum individual (percent)

	F1	F2	F3
Vegetables	70.0	0.0	30.0
Meat	44.2	0.0	55.8
Milk	39.9	0.0	60.1

For population exposure estimates, the AIRDOS-EPA code determines the imported fraction needed to supply the nutritional requirements of the entire population within 80 km. The quantity of food that is not imported is assumed to be grown or produced throughout the entire assessment area and consumed by the population within the assessment area as an average value for the entire assessment area. The surplus food grown at a given site we assumed was shipped outside the assessment area. We did not calculate dose for this exported fraction.

The ingestion pathway is handled by the terrestrial model (NRC77) portion of the AIRDOS-EPA code. The input values shown in Table K.4 were used and are independent of location and radionuclide. Selected terrestrial pathway parameters, which are radionuclide dependent, are given in Table K.5.

K.7 AIRDOS-EPA Output

An example output of AIRDOS-EPA can be found in the AIRDOS-EPA manual (Mo79). Doses calculated by AIRDOS-EPA were not used in this report. Another code, DARTAB, performed dose and risk estimates based on air and ground concentrations and ingestion and inhalation intakes and working levels calculated by AIRDOS-EPA. An explanation of the DARTAB code can be found in

Table K.4 Selected Input Parameters to AIRDOS-EPA

SYMBOLIC VARIABLE	DESCRIPTION	VALUE
PR	Plume rise	0.0 m
PH	Release height	1.0 m
BRTHRT	Human breathing rate	9.17E+5 cm^3/hr
T	Buildup time for surface deposition	source dependent
DD1	Fraction of radioactivity retained on leafy vegetables and produce after washing	1.0
TSUBH1	Time delay-ingestion of pasture grass by animals	0.0 hr
TSUBH2	Time delay-ingestion of stored feed by animals	2.16E+3 hr
TSUBH3	Time delay-ingestion of leafy vegetables by man	3.36E+2 hr
TSUBH4	Time delay-ingestion of produce by man	3.36E+2 hr
LAMW	Removal rate constant for physical loss by weathering	2.1E-3 hr^{-1}
TSUBE1	Period of exposure during growing season-pasture grass	7.2E+2 hr
TSUBE2	Period of exposure during growing season-crops or leafy vegetables	1.44E+3 hr
YSUBV1	Agricultural productivity by unit area (grass-cow-milk-man pathway)	0.28 kg/m^2
YSUBV2	Agricultural productivity by unit area (produce or leafy vegetables ingested by man)	0.716 kg/m^2
FSUBP	Fraction of year animals graze or pasture	0.40
FSUBS	Fraction of daily feed that is pasture grass when animals graze on pasture	0.43
QSUBF	Consumption rate of contaminated feed or forage by an animal (dry weight)	15.6 kg/day
TSUBF	Transport time from animal feed-milk-man	2.0 days

Table K.4 (Continued)

SYMBOLIC VARIABLE	DESCRIPTION	VALUE
UV	Rate of ingestion of produce by man	1.76E+2 kg/yr[a]
UM	Rate of ingestion of milk by man	1.12E+2 l/yr
UF	Rate of ingestion of meat by man	85.0 kg/yr
UL	Rate of ingestion of leafy vegetables by man	18.0 kg/yr
TSUBS	Average time from slaughter of meat animal to consumption	20.0 days
FSUBG	Fraction of produce ingested grown in garden of interest	1.0
FSUBL	Fraction of leafy vegetables grown in garden of interest	1.0
TSUBB	Period of long-term buildup for activity in soil	Same as T
P	Effective surface density of soil (dry weight) (assumes 15 cm plow layer)	2.15E+2 kg/m^2
TAUBEF	Fraction of meat producing herd slaughtered per day	3.81E-3 day^{-1}
MSUBB	Muscle mass of meat producing animal at slaughter	2.0E+2 kg
VSUBM	Milk production of cow	11.0 l/day
R1	Fallout interception fraction for pasture	0.57
R2	Fallout interception for vegetable crops	0.20

[a] This value, which was used in our analysis, is conservative because it includes fruit consumption. Without fruit consumption, the ingestion rate is 122 kg/yr.

Table K.5 Selected terrestrial pathway parameters by radionuclide

Radionuclide	Environmental Removal Rate (day^{-1})	B_{iv1} [a]	B_{iv2} [b]	Milk-transfer Coefficient F_m(day/l)	Meat-transfer Coefficient F_f (day/kg)
Uranium-238	7.06E-7	2.1E-2	4.2E-3	1.4E-4	1.6E-6
Uranium-235	7.06E-7	2.1E-2	4.2E-3	1.4E-4	1.6E-6
Uranium-234	7.06E-7	2.1E-2	4.2E-3	1.4E-4	1.6E-6
Thorium-232	5.61E-8	6.3E-3	3.5E-4	5.0E-6	1.6E-6
Thorium-230	5.61E-8	6.3E-3	3.5E-4	5.0E-6	1.6E-6
Thorium-228	5.61E-8	6.3E-3	3.5E-4	5.0E-6	1.6E-6
Actinium-228	2.12E-6	1.0E-2	2.5E-3	2.0E-5	1.6E-6
Radium-228	2.12E-5	1.0E-1	7.2E-2[c]	5.9E-4	5.0E-4
Radium-226	2.12E-5	1.0E-1	7.2E-2[c]	5.9E-4	5.0E-4
Radium-224	2.12E-5	1.0E-1	7.2E-2[c]	5.9E-4	5.0E-4
Radon-222	0.0	0.0	0.0	0.0	0.0
Bismuth-214	2.09E-4	6.0E-1	1.5E-1	5.0E-4	1.7E-2
Bismuth-212	2.09E-4	6.0E-1	1.5E-1	5.0E-4	1.3E-2
Lead-214	5.31E-7	1.4E-1	4.8E-3	8.7E-5	9.1E-4
Lead-212	5.31E-7	1.4E-1	4.8E-3	8.7E-5	9.1E-4
Lead-210	5.31E-7	1.1E-1	3.9E-3	9.9E-5	9.1E-4
Polonium-210	8.93E-6	4.2E-3	2.6E-4	1.2E-4	8.7E-3
Thallium-208	9.84E-4	1.0E+0	2.5E-1	2.3E-2	4.0E-2

(a) B_{iv1} = $\frac{\text{Radionuclide concentration in entire above-ground portion of pasture grasses at maturity per unit dry weight}}{\text{Radionuclide concentration in soil per unit dry weight}}$
= $\frac{\text{pCi/kg dry weight}}{\text{pCi/kg dry soil}}$

(b) B_{iv2} = $\frac{\text{Radionuclide concentration in edible portion of leafy vegetables and fresh produce at maturity per unit fresh weight}}{\text{Radionuclide concentration in soil per unit dry weight}}$
= $\frac{\text{pCi/kg wet weight}}{\text{pCi/kg dry soil}}$

(c) This value, which was used in our analysis is conservatively high. Using data from DeBortoli (De72) for vegetables and grain products, a more realistic value would be 2.6E-3.

Appendix L. Concentrations and intakes computed by AIRDOS-EPA are by radionuclide and receptor location. Table K.6 lists values for effective radioactive decay constants, assumed for the plume (air) and ground surface, which influence the concentration and intake estimates. The values chosen for the decay constants attempt to account for daughter buildup in the air and on the ground surface.

Table K.6 Effective radioactive decay constants

Radionuclide	Decay constant in plume (day^{-1})	Decay constant on ground surface (day^{-1})
Uranium-238	4.25E-13	4.25E-13
Uranium-235	2.68E-12	2.68E-12
Uranium-234	7.77E-9	7.77E-9
Thorium-232	1.35E-13	1.35E-13
Thorium-230	2.47E-8	2.47E-8
Thorium-228	9.92E-4	1.35E-13
Actinium-228	2.72E+0	1.35E-13
Radium-228	3.30E-4	1.35E-13
Radium-226	1.19E-6	1.19E-6
Radium-224	1.89E-1	1.35E-13
Radon-222	1.81E-1	1.81E-1
Bismuth-214	1.81E-1	1.19E-6
Bismuth-212	1.35E-13	1.35E-13
Lead-214	1.81E-1	1.19E-6
Lead-212	1.35E-13	1.35E-13
Lead-210	8.52E-5	1.19E-6
Polonium-210	5.02E-3	1.19E-6
Thallium-208	1.35E-13	1.35E-13

K.8 References

At74 Athey, T.W., Tell, R.A. and Janes, D.E., 1974, "The Use of an Automated Data Base in Population Exposure Calculations", from Population Exposures, Health Physics Society, Conf-74018.

De72 DeBortoli, M. and Gaglione, P., 1972, "Radium-226 in Environmental Materials and Foods", Health Phys. 22, 43-48.

Ho72 Holzworth, G.C., 1972, "Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States", U.S. Office of Air Programs, Report AP-101.

Mo79 Moore, R.E., et al., 1979, "AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides", EPA 520/1-79-009 (Reprint of ORNL-5532).

NRC75 Nuclear Regulatory Commission, Radiological Assessment Branch, Division of Technical Review, 1975, "Code Input Data for Man-Rem Estimates", memo by K. Eckerman, N. Dayem and R. Emch.

NRC77 Nuclear Regulatory Commission, Office of Standards Development, 1977, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 20 CFR Part 50, Appendix I", Regulatory Guide 1.109, Revision 1, October 1977.

USDA72 United States Department of Agriculture, Agricultural Research Service, 1972, "Food Consumption of Households in the United States (Seasons and Year 1965-1966)", Household Food Consumption Survey 1965-1966, Report No. 12.